Serial No.: 10/822,358
Amdt. dated 26 April 2006
Reply to Office Action of 26 Jan. 2006

Amendments to the Claims:

This listing of claims will replace all prior versions and listings of claims in the application:

Listing of Claims:

1. (Currently amended) A system for delivering a desired mass of gas, comprising:

a chamber;

a first valve controlling gas flow into the chamber;

a second valve controlling gas flow out of the chamber;

a pressure transducer providing measurements of pressure within the chamber;

~~an input device for providing a desired mass of gas to be delivered from the system;~~

a controller connected to the valves and the pressure transducer ~~and the input device and~~, wherein the controller is configured and arranged ~~programmed~~ to[[,]]

(i) receive ~~the~~ a desired mass flow setpoint from an ~~of gas through the~~ input device[[,]];

(ii) close the second valve;

(iii) open the first valve;

(iv) receive chamber pressure measurements from the pressure transducer;

(v) close the first ~~inlet~~ valve when pressure within the chamber reaches a predetermined level;

(vi) wait a predetermined waiting period to allow the gas inside the chamber to approach a state of equilibrium;

(vii) open the second ~~outlet~~ valve at time = t_0;

(viii) calculate a value of the total mass delivered as the second valve is open and as a function of temperature and pressure within the chamber; and

(ix) close the second ~~outlet~~ valve at time = t* when the calculated value of total mass delivered ~~of gas discharged~~ equals the desired mass flow setpoint.

2. (Currently amended) A system according to claim 1, wherein the mass delivered ~~discharged~~ Δm at time t* is equal to,

$$\Delta m = m(t_0) - m(t^*) = (V/R)[(P(t_0)/T(t_0)) - (P(t^*)/T(t^*))] \qquad [[(5)]]$$

wherein $m(t_0)$ is the mass of the gas in the ~~delivery~~ chamber at time = t_0 when the gas inside the chamber is at a state of equilibrium, m(t*) is the mass of the gas in the ~~delivery~~ chamber at time = t*, V is the volume of the ~~delivery~~ chamber, R is equal to the ~~universal~~ ideal gas constant (~~8.3145~~ J/ Kg ~~mol~~ K), $P(t_0)$ is the pressure in the chamber at time = t_0, P(t*) is the pressure in the chamber at time = t*, $T(t_0)$ is the temperature in the chamber at time = t_0, and T(t*) is the temperature in the chamber at time = t*.

3. (Currently amended) A system according to claim 2, further comprising a temperature probe secured to the ~~delivery~~ chamber and connected to the controller, wherein the temperature probe ~~directly~~ provides $T(t_0)$ and T(t*) to the controller.

4. (Currently amended) A system according to claim 3, wherein the chamber includes a chamber wall, and ~~further comprising a temperature probe secured to the delivery chamber and connected to the controller and~~ wherein $T(t_0)$ and T(t*) are calculated by the controller using:

$$dT/dt = -(\rho_{STP}/\rho V)Q_{out}(\gamma-1)T + (Nu\,\kappa/l)(A_w/VC_v\rho)(T_w - T) \qquad [[(3)]]$$

wherein ~~where~~ ρ_{STP} is the gas density under standard temperature and pressure (STP) conditions, ρ equals the density of the gas, V is the volume of the chamber, Q_{out} is the gas flow out of the ~~delivery~~ chamber, T equals absolute temperature, γ is the ratio of specific heats, Nu is Nusslets number, κ is the thermal conductivity of the gas, C_v is the specific heat of the gas under constant volume, l is the characteristic length of the ~~delivery~~ chamber, and T_w is the temperature of the wall of the chamber as provided by the temperature probe.

5. (Currently amended) A system according to claim 4, wherein the gas flow out of the ~~delivery~~ chamber is calculated using:

$$Q_{out} = -(V/\rho_{STP})[(1/RT)(d\rho/dt)-(P/RT^2)(dT/dt)] \qquad [[(4)]]$$

6. (Currently amended) A system according to claim 1, wherein the value of the predetermined level of pressure is provided through the input device.

7. (Currently amended) A system according to claim 1, wherein the value of the predetermined waiting period is provided through the input device.

8. (Currently amended) A system according to claim 1, further comprising an output device connected to the controller, and wherein the controller is ~~programmed~~ configured and arranged so as to provide ~~the mass of gas discharged~~ to the output device an indication of the mass delivered.

9. (Currently amended) A system according to claim 1, wherein the chamber is a delivery chamber. further comprising a process chamber connected to the delivery chamber through the second valve.

10. (Original) A system according to claim 1, wherein the pressure transducer has a response time of about 1 to 5 milliseconds.

11. (Original) A system according to claim 1, wherein the second valve has a response time of about 1 to 5 milliseconds.

12. (Withdrawn) A method for delivering a desired mass of gas, comprising:

providing a chamber;

receiving a desired mass of gas to be delivered from the chamber;

preventing gas flow out of the chamber;

allowing gas flow into the chamber;

measuring pressure within the chamber;

preventing further gas flow into the chamber when pressure within the chamber reaches a predetermined level;

waiting a predetermined waiting period to allow the gas inside the chamber to approach a state of equilibrium;

allowing gas flow out of the chamber at time = t_0; and

stopping gas flow out of the chamber at time = t^* when the mass of gas discharged equals the desired mass.

13. (Withdrawn) A method according to claim 12, wherein the mass discharged Δm is equal to,

$$\Delta m = m(t_0) - m(t^*) = V/R[(P(t_0)/T(t_0)) - (P(t^*)/T(t^*))] \qquad (5)$$

wherein $m(t_0)$ is the mass of the gas in the delivery chamber at time = t_0, $m(t^*)$ is the mass of the gas in the delivery chamber at time = t^*, V is the volume of the delivery chamber,

R is equal to the universal gas constant (8.3145 J/mol K), $P(t_0)$ is the pressure in the chamber at time $= t_0$, $P(t^*)$ is the pressure in the chamber at time $= t^*$, $T(t_0)$ is the temperature in the chamber at time $= t_0$, $T(t^*)$ is the temperature in the chamber at time $= t^*$.

14. (Withdrawn) A method according to claim 13, further comprising measuring a temperature of a wall of the delivery chamber and the temperature measurements of the wall directly provide $T(t_0)$ and $T(t^*)$ to the controller.

15. (Withdrawn) A method according to claim 13, further comprising measuring a temperature of a wall of the delivery chamber and wherein $T(t_0)$ and $T(t^*)$ are calculated using:

$$dT/dt = (\rho_{STP}/\rho V)Q_{out}(\gamma-1)T + (Nu\ \kappa/l)(A_w/VC_v\rho)(T_w - T) \quad (3)$$

where ρ_{STP} is the gas density under standard temperature and pressure (STP) conditions, ρ equals the density of the gas, V is the volume of the chamber, Q_{out} is the gas flow out of the delivery chamber, T equals absolute temperature, γ is the ratio of specific heats, Nu is Nusslets number, κ is the thermal conductivity of the gas, C_v is the specific heat of the gas under constant volume, l is the characteristic length of the delivery chamber, and T_w is the temperature of the wall of the chamber.

16. (Withdrawn) A method according to claim 15, wherein the gas flow out of the delivery chamber is calculated using:

$$Q_{out} = -(V/\rho_{STP})[(1/RT)(d\rho/dt)-(P/RT^2)(dT/dt)] \quad (4)$$

17. (Withdrawn) A method according to claim 12, wherein the predetermined level of pressure is received through an input device.

18. (Withdrawn) A method according to claim 12, wherein the predetermined waiting period is received through an input device.

19. (Withdrawn) A method according to claim 12, further comprising providing the mass of gas discharged to the output device to an output device.

20. (Withdrawn) A method according to claim 12, further comprising connecting a process chamber to the delivery chamber for receiving the mass of gas discharged from the delivery chamber.

21. (New) A system for delivering a desired quantity of mass of gas, comprising:

a chamber including an inlet and outlet;

an inlet valve, connected to the inlet, configured and arranged so as to control the flow of gas into the chamber through the inlet;

an outlet valve, connected to the outlet, configured and arranged so as to control the flow of gas from the chamber through the outlet; and

a controller configured and arranged to control the inlet and outlet valves so that (a) gas can flow into the chamber until the pressure within the chamber reaches a predetermined level, (b) the pressure of gas within the chamber can reach a state of equilibrium, and (c) a controlled amount of mass of the gas can then be measured and allowed to flow from the chamber as a function of a setpoint corresponding to a desired mass, and the temperature and pressure in the chamber.

22. (New) A system according to claim 21, further including a pressure sensor constructed and arranged so as to provide a pressure measurement signal to the controller as a function of the pressure within the chamber, and a temperature sensor constructed and arranged so as to provide a temperature measurement signal to the controller as a function of the temperature within the chamber.

23. (New) A system according to claim 21, wherein the amount of mass of gas flowing from the chamber, Δm at time t^*, is determined by the controller as follows:

$$\Delta m = m(t_0) - m(t^*) = (V/R)[(P(t_0)/T(t_0)) - (P(t^*)/T(t^*))],$$

wherein $m(t_0)$ is the mass of the gas in the chamber at time = t_0 when the gas within the chamber is at a state of equilibrium, $m(t^*)$ is the mass of the gas in the chamber at time = t^*, V is the volume of the chamber, R is equal to the ~~universal~~ ideal gas constant (~~8.3145~~ J/ Kg-~~mol~~ K), $P(t_0)$ is the pressure in the chamber at time = t_0, $P(t^*)$ is the pressure in the chamber at time = t^*, $T(t_0)$ is the temperature in the chamber at time = t_0, $T(t^*)$ is the temperature in the chamber at time = t^*.

24. (New) A system according to claim 21, wherein the controller is further configured and arranged to control operation of the inlet valve by control commands.

25. (New) A system according to claim 21, wherein the chamber includes a chamber wall, and further comprising a temperature sensor configured and arranged to sense a temperature of the chamber wall T_w, and produce a corresponding temperature signal, and wherein $T(t_0)$ and $T(t^*)$ are the measured temperatures of the chamber wall at times t_0 and t^*, respectively.

26. (New) A system according to claim 25, wherein the controller is configured and arranged so that a controlled amount of mass of the gas can be allowed to flow from the chamber as a function a time derivative of the temperature $dT/dt = -(\rho_{STP}/\rho V)Q_{out}(\gamma-1)T + (Nu\,\kappa/l)(A_w/VC_v\rho)(T_w - T)$, wherein ρ_{STP} is the gas density under standard temperature and pressure (STP) conditions, ρ equals the density of the gas, V is the volume of the chamber, Q_{out} is the gas flow out of the chamber, T equals absolute temperature, γ is the ratio of specific heats, Nu is Nusslets number, κ is the thermal conductivity of the gas, C_v is the specific heat of the gas under constant volume, l is the characteristic length of the chamber, and T_w is the temperature of the wall of the chamber as provided by the temperature sensor.

27. (New) A system according to claim 21, wherein the outlet valve has a response time of about 1 ms to about 5 ms.

28. (New) A system according to claim 21, wherein the response time of the outlet valve

is about 2 ms to about 5 ms.

29. (New) A system according to claim 21, wherein the pressure sensor has a response time of about 1 ms to about 5 ms.

30 (New) A system according to claim 21, wherein the chamber is a delivery chamber, and further comprising a process chamber connected to the delivery chamber through the outlet valve.

31. (New) An atomic layer deposition system including a semiconductor processing chamber, comprising:

a mass delivery control system configured and arranged to repeatedly deliver pulses of precisely metered quantities of a precursor gas, each pulse of a desired predetermined mass, to the semiconductor process chamber, wherein the metered quantity of each pulse is measured as the pulse of gas is being delivered to the semiconductor process chamber.

32. (New) An atomic layer deposition system according to claim 31, wherein the mass delivery control system is configured and arranged to repeatedly deliver pulses of precisely metered quantities of at least two precursor gases, each pulse of a desired predetermined mass, to the semiconductor process chamber, wherein the metered quantity of each pulse is measured as the respective pulse of gas is being delivered to the semiconductor process chamber.

33. (New) An atomic layer deposition system according to claim 31, wherein the mass delivery control system includes a delivery chamber and controls the introduction of gas into and out of the delivery chamber so that (a) gas can flow into the delivery chamber until the pressure within the delivery chamber reaches a predetermined level, (b) the pressure of gas within the delivery chamber can reach a state of equilibrium, and (c) a controlled amount of mass of the gas can then be allowed to flow from the delivery chamber to the process chamber as a function of a setpoint corresponding to the desired predetermined mass, and the temperature and pressure in the delivery

chamber so that a metered quantity of gas is measured as the pulse of gas is delivered to the semiconductor process chamber.

34. (New) An atomic layer deposition system comprising:

a mass delivery control system configured and arranged to repeatedly deliver pulses, each of a predetermined mass, of at least one precursor gas to a processing chamber, the mass delivery control system including:

(i) a delivery chamber including an inlet and outlet;

(ii) an inlet valve, connected to the inlet, configured and arranged so as to control the flow of precursor gas into the delivery chamber through the inlet;

(iii) an outlet valve, connected to the outlet and configured and arranged so as to control the flow of gas from the delivery chamber through the outlet; and

(iv) a controller configured and arranged to control the inlet and outlet valves so that for each pulse of precursor gas (a) gas can flow into the delivery chamber until the pressure within the delivery chamber reaches a predetermined level, (b) the pressure of gas within the delivery chamber can reach a state of equilibrium, and (c) a controlled amount of mass of the gas can then be allowed to flow from the delivery chamber as a function of a setpoint corresponding to a desired mass, and the temperature and pressure in the delivery chamber so that a metered quantity of gas is measured as the pulse of gas is delivered to the semiconductor process chamber; and

a process chamber, coupled to the outlet and configured and arranged to repeatedly receive the pulses of precursor gas.

35. (New) The atomic layer deposition system of claim 34, further including a mixing manifold, coupled to the inlet of the mass delivery control system and having a first inlet for

receiving a carrier gas and at least a second inlet for receiving the precursor gas so that the precursor gas is mixed with the carrier gas when received by the mass delivery control system.

36. (New) The atomic layer deposition system of claim 35, further including:

a plasma forming zone configured and arranged to receive a gas from the mixing manifold and to form a plasma from the received gas; and

a process chamber configured and arranged hold a wafer and to receive a plasma from the plasma forming zone.

37. (New) The atomic layer deposition system of claim 34, wherein a mass delivery control system configured and arranged to alternately deliver pulses, each of a predetermined mass, of at least two precursor gases to a processing chamber.

38. (New) A system according to claim 34, further including a pressure sensor constructed and arranged so as to provide a pressure measurement signal to the controller as a function of the pressure within the delivery chamber, and a temperature sensor constructed and arranged so as to provide a temperature measurement signal to the controller as a function of the temperature within the delivery chamber.

39. (New) A system according to claim 34, wherein the amount of mass of gas flowing from the delivery chamber, Δm at time t^*, is determined by the controller as follows:

$$\Delta m = m(t_0) - m(t^*) = (V/R)[(P(t_0)/T(t_0)) - (P(t^*)/T(t^*))],$$

wherein $m(t_0)$ is the mass of the gas in the delivery chamber at time $= t_0$ when the gas within the delivery chamber is at a state of equilibrium, $m(t^*)$ is the mass of the gas in the delivery chamber at time $= t^*$, V is the volume of the delivery chamber, R is equal to the ideal gas constant (J/ Kg-K), $P(t_0)$ is the pressure in the delivery chamber at time $= t_0$, $P(t^*)$ is the pressure in the delivery

chamber at time = t^*, $T(t_0)$ is the temperature in the delivery chamber at time = t_0, $T(t^*)$ is the temperature in the delivery chamber at time = t^*.

40. (New) A system according to claim 34, wherein the controller is further configured and arranged to control operation of the mass delivery control system inlet valve by control commands.

41. (New) A system according to claim 34, wherein the delivery chamber includes a chamber wall, and further comprising a temperature sensor configured and arranged to sense a temperature of the chamber wall T_w, and produce a corresponding temperature signal, and wherein $T(t_0)$ and $T(t^*)$ are the measured temperatures of the chamber wall at times t_0 and t^*, respectively.

42. (New) A system according to claim 41, wherein controller is configured and arranged so that a controlled amount of mass of the gas can be allowed to flow from the delivery chamber as a function a time derivative of the temperature $dT/dt = -(\rho_{STP}/\rho V)Q_{out}(\gamma-1)T + (Nu\ \kappa/l)(A_w/VC_v\rho)(T_w - T)$, wherein ρ_{STP} is the gas density under standard temperature and pressure (STP) conditions, ρ equals the density of the gas, V is the volume of the delivery chamber, Q_{out} is the gas flow out of the delivery chamber, T equals absolute temperature, γ is the ratio of specific heats, Nu is Nusslets number, κ is the thermal conductivity of the gas, C_v is the specific heat of the gas under constant volume, l is the characteristic length of the delivery chamber, and T_w is the temperature of the wall of the delivery chamber as provided by the temperature sensor.

43. (New) A system according to claim 34, wherein the mass delivery control system outlet valve has a response time of about 1 ms to about 5 ms.

44. (New) A system according to claim 34, wherein the response time of the mass delivery control system outlet valve is about 2 ms to about 5 ms.

45. (New) A system according to claim 34, wherein the mass delivery control system pressure sensor has a response time of about 1 ms to about 5 ms.

46. (New) A system according to claim 34, wherein the at least one mass delivery control system includes two mass delivery control systems.

47. (New) A system according to claim 34, wherein the process chamber includes a wafer support and heater coupled to the wafer support for heating the wafer support and wafer for plasma deposition.

48. (New) A system according to claim 34, further including a throttling valve and vacuum pump connected to the process chamber and configured and arranged to draw gas flow across a surface of the wafer and regulate pressure within the process chamber.

49. (New) A method of repeatedly delivering pulses of metered quantities of a precursor gas to a semiconductor processing chamber, comprising:

repeatedly delivering pulses of precisely metered quantities of the precursor gas, each pulse of a desired predetermined mass, to the semiconductor process chamber; wherein repeatedly delivering the pulses includes measuring the mass of each pulse of gas as each pulse is delivered to the semiconductor process chamber.

50. (New) A method according to claim 49, further including repeatedly delivering pulses of precisely metered quantities of at least two precursor gases, wherein the metered quantity of each pulse is measured as the respective pulse of gas is being delivered to the semiconductor process chamber.

51. (New) A method according to claim 49, wherein repeatedly delivering pulses of precisely metered quantities of the precursor gas includes introducing the gas into and out of the delivery chamber so that (a) gas can flow into the delivery chamber until the pressure within the delivery chamber reaches a predetermined level, (b) the pressure of gas within the delivery chamber can reach a state of equilibrium, and (c) a controlled amount of mass of the gas can then be allowed to flow from the delivery chamber to the process chamber as a function of a setpoint corresponding

to the desired predetermined mass, and the temperature and pressure in the delivery chamber so that a metered quantity of gas is measured as the pulse of gas is delivered to the semiconductor process chamber.

52. (New) A method of repeatedly delivering pulses of metered quantities of a precursor gas to a semiconductor processing chamber, comprising:

(a) accumulating the gas within a delivery chamber until the pressure within the chamber reaches a predetermined level;

(b) waiting a predetermined waiting period to allow the gas within the delivery chamber to approach a state of equilibrium; and

(c) measuring the mass of the gas as it flows from the delivery chamber to the semiconductor processing chamber so that a precise metered amount of gas is delivered to the semiconductor processing chamber.

53. (New) A method according to claim 52, wherein (a)-(c) are repeated so that pulses of at least two precursor gases are repeatedly delivered to the semiconductor processing chamber.